California Climate Action Registry

Cement Reporting Protocol

Draft

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Introduction

The California Climate Action Registry (Registry) is a non-profit public/private partnership created by the California Legislature in 2000 to serve as a voluntary greenhouse gas (GHG) registry that promotes and facilitates measuring, monitoring and reducing GHG emissions. The Registry's Cement Reporting Protocol provides guidance on accounting and reporting GHG emissions for cement companies. It adopts the process-emissions calculation methodology in The Cement CO_2 Protocol from the World Business Council for Sustainable Development's (WBCSD) Cement Sustainability Initiative.[1]

The Cement Reporting Protocol is an appendix to the Registry's General Reporting Protocol (GRP). The latter provides principles, procedures, and methodologies to guide entities in accounting for and reporting entity-level GHG emissions to the Registry. The GRP is designed to support the complete, transparent, accurate, and consistent reporting of an organization's absolute GHG emissions inventory. Although cement companies produce GHG emissions from multiple sources – e.g., trucks, heaters, kilns – the Cement Reporting Protocol focuses on calculating *process* CO_2 emissions associated with manufacturing cement: the calcination of raw materials. It augments the GRP's general guidance, with explicit process-related CO_2 emission calculation methodologies. In addition to assisting cement companies in calculating their absolute emissions (in tons of CO_2 equivalent per year), the Cement Reporting Protocol supports the reporting of GHG emission metrics, which allow reporters to normalize emissions over a common unit of measurement (i.e. ton of CO_2 per ton of product).

Cement companies must follow the GHG emission accounting procedures and reporting parameters in both the GRP and the Cement Reporting Protocol. When used together, these protocols form a complete set of guidance documents for cement companies reporting to the Registry. They lay out the Registry's reporting process and parameters, guide cement manufacturers through the GHG emission calculation process and facilitate reporting this data via the Registry's standardized reporting mechanism, its web-based reporting system (the Climate Action Registry Reporting Online Tool or CARROT). The protocols do not provide guidance on calculating emissions reductions from projects.

The Cement Reporting Protocol begins with a brief discussion of the GHG emission reporting topics covered in the Registry's GRP and this guidance document; next, it summarizes the Registry's reporting parameters and then provides an overview of GHG emissions from cement manufacturing. The heart of the protocol details the procedure to

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[1] *The Cement CO_2 Protocol: CO2 Accounting and Reporting Standard for the Cement Industry,* Version 2.0, June 2005, The Cement Sustainability Initiative, WBCSD

calculate direct process CO_2 emissions from cement manufacturing and determine an efficiency metric; lastly, it discusses other GHG emission sources and certification issues.

GHG Emissions Reporting Guidance in the GRP and Cement Reporting Protocol

The Registry recommends that cement companies first familiarize themselves with the GRP before turning to the Cement Reporting Protocol. The GRP describes the Registry's basic registration and reporting process and explains the parameters that determine which sources of emissions must be included in a company's inventory, based on their location and the reporter's organizational structure and operations. It provides general guidance for reporting all basic types of direct and indirect GHG emissions and also serves as the key resource for instructing reporters in completing and submitting their emission report (e.g. determining *de minimis* emissions, establishing and updating a GHG emission baseline, preparing and submitting an annual report using CARROT and understanding certification).

As mentioned above, the Cement Reporting Protocol focuses on calculating *process* CO_2 emissions associated with manufacturing cement.[2] Box 1 shows the areas covered by the GRP and the Cement Reporting Protocol and assists reporters in navigating the documents to understand the Registry's reporting requirements and procedures.

[2] The Registry accounts for GHG emissions according to the type of the emission source. For example, emissions from automobiles and cement hauling trucks owned by the reporting company are classified as direct emissions from mobile combustion. And importantly for cement companies, emissions from the calcinations of raw materials are be classified as direct process emissions.

Box 1: Registry Reporting Protocols for the Cement Sector

General Reporting Protocol Guidance

Reporting parameters
- Geographic boundaries
- Organizational boundaries
- Operational boundaries
- Using CARROT
- Establishing and updating a baseline

Quantifying GHG emissions
- Mobile sources
- Stationary combustion sources
- Process
- Fugitive
- Purchased and consumed electricity
- Purchased and consumed steam/heat

Completing and Submitting Report
- *De Minimis* Emissions
- Understanding CARROT and certification

Cement Reporting Protocol Guidance

Process CO_2 emissions from cement manufacturing: procedure for the clinker-based method

Efficiency metric for cement companies

(Cement-based method in Appendix A)

Registry Reporting Parameters

The basic unit of participation in the Registry is the cement company in its entirety. At a minimum, participants must report entity-wide (total) emissions, which covers significant mobile and stationary fossil fuel combustion sources, process-related emission sources, fugitive emission sources, fugitive sources, and indirect sources like electricity consumption. The Registry strongly encourages the reporting of GHG emissions information at the facility- or source-level as part of the entity-level report. Although facility-level reporting may require more data collection and organization work, it will provide a more detailed and comprehensive picture of the company's emissions profile and could reduce certification costs.

As mentioned above, the Registry's GRP serves as the main resource regarding these topics; this protocol highlights key points.

Basic Reporting Requirements

Registry participants must report their GHG emissions to the Registry each year. Any entity that conducts business activities in the State of California or the U.S. may join the Registry. If a company does not have operations or emissions in California, then it may report its total U.S. emissions, and indicate that California emissions are zero. At a minimum, participants must report at least 95% of their entity-wide GHG emissions.

Participants annually submit their GHG emission reports to the Registry. Each report must contain at least the following information:

- The geographic scope of the Emission Report (whether California-only or nationwide);
- The organizational and operational boundaries of the reporting entity for which GHG emission data is reported;
- Total significant direct GHG emissions (including mobile and stationary combustion, process, and fugitive);[3] and
- Total significant indirect GHG emissions (from electricity usage, co-generation, steam imports and district heating and cooling).

Before an emission report will be accepted by the Registry, the inventory must be verified by an approved certifier. The Registry's Cement Certification Protocol (CCP) provides guidance for certifiers to conduct an independent, objective review of the emission reports. Approved certifiers are screened and approved by the State of California and the Registry to ensure that they have the necessary qualifications to appropriately evaluate emission reports. The certification process ensures that the GHG emissions inventory is complete and comprehensive, consistent across time, comparable across sectors, conducted in a reproducible and transparent manner, and accurate.

The following sections regarding boundary considerations provide an overview of the process for identifying emission sources included in an inventory.

Geographic Boundaries

This section reviews the requirements for determining the geographic boundaries of the GHG emission report detailed in the GRP.

The Registry provides two options for defining the scope of an emission inventory:

1. All GHG emissions in California (CA reporting), or
2. All GHG emissions in the U.S. – separated into California and non-California inventories (U.S. reporting).[4]

Companies report their GHG emissions based on where the emissions are generated. Companies within the U.S. that do not have any operations in California are welcome to report their GHG emissions with the Registry. The Registry does not limit membership only to companies that have operations in California.

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[3] For the purposes of the Registry, significant GHG emissions refer to a source that produces emissions in excess of 5% of the total GHG inventory. An insignificant source is less than 5% of reported emissions. See the GRP for further guidance.

[4] The Registry does not currently certify GHG emissions data from operations outside the U.S. However, reporters are encouraged to gather and retain this data for reporting to the Registry in subsequent years. International emissions data can be recorded in a participant's emission report in the optional section.

Organizational Boundaries

After determining geographic boundaries, reporters should select an approach to determine emission accounting and reporting responsibility – called setting organizational boundaries. For those facilities that are wholly-owned report all of the associated emissions. For those facilities in which the reporter has partial ownership share, a lease, or holds an operating license, the Registry provides two options for determining what share of emissions should be reported:

- **Option 1 – Management Control:** The participant should report 100% of the emissions if it has control over financial, operational, health, safety, and/or environmental policies.[5]
- **Option 2 – Equity Share:** The participant should report a percentage of the emissions, based on its share of financial ownership in the entity.[6]

As in the GRP, Registry participants can choose to report based on management control, equity share, or report based on both management control and equity share. The method chosen, though, must apply to all facilities, for every year reported to the Registry. *Please note that management control is the default method CARROT uses to calculate emissions.*

Figure 1 provides a birds-eye view of a cement plant, from the quarry to product shipment. It illustrates the scope of the boundaries cement companies should consider when developing an emission inventory.

[5] Reporters that operate a leased facility should report according to management control. Refer to the GRP for criteria determining management control.
[6] These options assume that there are no other contractual ownership arrangements in place. Contracts may serve to clarify ownership and organizational boundaries.

Figure 1: Snapshot of cement sector operations.

Operational Boundaries

The final boundary consideration involves classifying emissions as either direct or indirect. As explained above, direct emissions are produced by sources a reporter owns or controls, whereas indirect emissions are produced by sources owned or controlled by another entity; direct emissions include mobile combustion, stationary combustion, fugitive emissions, and process emissions; indirect emissions include purchases and consumption of electricity, steam, and/or heat. Reporters are required to inventory all significant direct and indirect emissions.

Generally, direct and indirect sources include: quarry trucks and other quarry equipment, raw material processing equipment such as grinders, mixers dehydrators and precalcinators, cement kilns (both a stationary combustion source and a process emission source), cement grinding and blending equipment, fuel and product transport (either trucks or rail), and electricity/steam/heat consumption facilities.

Other Reporting Requirements

As indicated above, the Registry's GRP provides comprehensive guidance on the Registry's reporting parameters and process. In addition to a complete description of boundary considerations, cement companies should refer to the GRP for guidance on determining GHG emissions baselines, *de minimis* emissions, and for procedures to prepare and submit an annual GHG emission report using CARROT.

Overview of CO_2 Emissions from Manufacturing Cement

Manufacturing cement involves mixing small amounts of gypsum and/or anhydrite with finely ground clinker. Process CO_2 emissions are released into the atmosphere during the production of clinker and are directly associated with the amount of clinker created. Clinker is formed through a chemical conversion process – called calcination – in which calcium carbonate ($CaCO_3$) separates in a super heated kiln producing lime (CaO) and CO_2. The lime reacts with other raw materials in the kiln such as silica, aluminum, and iron oxides to form clinker; CO_2 is liberated as a byproduct.[7] The clinker production process generates the majority of CO_2 emissions associated with manufacturing cement.[8]

The preponderance of cement made today consists of portland cement, however, other varieties exist as well.[9] Blended cements, for example, add other cementitious products such as blast furnace slag to the cement mix which displace the amount of clinker needed. Therefore, using blended cements can significantly reduce the amount of CO_2 emitted by decreasing the amount of clinker used per unit of cement. On the other hand, masonry cement has a higher content of lime (CaO), thereby potentially increasing a cement company's CO_2 emissions depending on whether the CaO was produced on-site or provided by an outside vendor.

Two methodologies exist to calculate CO_2 emissions from producing cement: (1) the Clinker-Based Methodology and (2) the Cement-Based Methodology.[10] Theoretically, both approaches should yield the same level of CO_2 emissions, as long as accurate and precise data is available. The clinker-based approach calculates CO_2 emissions based on the volume and composition of clinker produced as well as the amount of cement kiln dust (CKD) not recycled to the kiln.[11,12] The cement-based approach accounts for changes in CO_2 emissions in cement production by incorporating modifications to the cement manufacturing process, i.e., making blended cements. It calculates CO_2 emissions based on the amount of raw materials and their carbonate content.

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[7] Magnesium carbonate ($MgCO_3$) can also be used to produce clinker. Like $CaCO_3$, heating $MgCO_3$ liberates CO_2.

[8] GHG emissions also result from combusting fossil fuels to power the cement manufacturing equipment. As indicated above, these emissions are categorized under direct emissions from stationary sources; guidance for reporting these emissions is found in the GRP.

[9] Developed in 1824 by Joseph Aspdin and named after the stone quarried on the Isle of Portland off the British coast, portland cement is a type of hydraulic cement that consists of a carefully proportioned chemical combination of calcium, silicon, iron, and aluminum.

[10] The clinker-based methodology is presented in *The Cement CO_2 Protocol* from WBCSD; the cement-based methodology is provided in *Calculating CO_2 Process Emissions from Cement Production,* October 2001 from ICF. Both approaches are considered appropriate calculation tools under the World Resources Institute's GHG Protocol Initiative. More information can be found at www.ghgprotocol.org.

[11] CKD consists of a mixture of raw materials and partially calcined material that did not become part of the clinker and not recycled back into the kiln. It is generated by all kilns at varying levels based on efficiency.

[12] Bypass dust, as opposed to CKD, is usually fully calcinated. Thus CO_2 emissions from bypass dust are accounted for while calculating the emissions associated with the clinker produced.

The Cement Reporting Protocol provides guidance on calculating emissions according to the clinker-based methodology, which has become industry standard. However, the Registry also presents the cement-based methodology in Appendix A.

The choice of which calculation methodology to use is largely dictated by how familiar a company is with a particular approach and data availability, as well as potentially by the types of cement a company produces. All cement companies know clinker production data and the CaO/MgO content of the clinker, thus the clinker-based approach is an appropriate standard. On the other hand, a company may choose to follow the cement-based methodology if it collects data on cement production, the raw material ratio to produce clinker and the $CaCO_3$ equivalent content of the raw materials. Ultimately, the difference between the two approaches is one of scope. That is, the clinker-based method focuses on the part of the cement manufacturing process that yields significant GHG emissions – clinker production. The cement-based method allows companies to monitor changes in emissions due to modifying the cement manufacturing process.

Although the Registry ultimately leaves it to the discretion of the cement company to determine which methodology best suits its needs, the preferred approach is the clinker-based methodology.

Direct Process CO_2 Emissions – Cement Manufacturing

This section provides guidance on calculating direct process-related emissions from cement production according to the clinker-based methodology.

Box 2: Using the Cement Reporting Protocol and the Registry's On-Line Reporting Tool (CARROT) to Calculate CO_2 Emission

Although the Cement Reporting Protocol describes the type of information needed to complete an inventory and explains how a company's activity data are used to calculate emissions, it does not enumerate every necessary data field for taking a GHG emission inventory. The Registry expects to update its on-line reporting tool (CARROT) to provide all necessary data fields for companies to input information to carry out the reporting process and perform many of the calculations described in this protocol. The Registry's CARROT serves as data storage and an emission calculation tool; it is described in more detail in the GRP.

The Clinker-Based Methodology

The clinker-based approach derives the process-related CO_2 emissions from the amount of clinker produced plus the amount of CKD not recycled to the kiln. The calculation generally takes the following form:

$$CO_2 \text{ emissions} = [(Cli)(EF_{Cli}) + (CKD)(EF_{CKD})]$$

Where:

Cli	=	Quantity of clinker produced
EF_{Cli}	=	Clinker emission factor
CKD	=	Quantity CKD discarded
EF_{CKD}	=	CKD emission factor

Equation 1: Calculating process-related CO_2 emissions according to the clinker-based methodology

Companies collect activity data (described below) on the quantity of clinker and the CaO/MgO content to develop both the clinker emission factor and the CKD emission factor. Alternatively, if poor data are available companies can choose to use default emission factors, provided below. CO_2 emissions from CKD not recycled to the kiln are estimated by determining the amount of CKD produced and the calcination rate of CKD; the CKD emission factor is calculated from the clinker emission factor and the degree of calcination. The following sections provide information on collecting activity data and determining a plant-specific emission factor.

Activity Data

To calculate CO_2 emissions through the clinker-based methodology companies need data on clinker production, CaO/MgO content, and non-carbonate sources of CaO and MgO.[13] Companies should also collect data on the amount of CKD not recycled to the kiln to derive its emission factor. The table below provides an indicative list of data needs at an aggregated level.

Activity Data for Clinker-Based CO_2 Estimation Method[14]	**Units**
Clinker produced	Mass
CaO content of clinker	%
MgO content of clinker	%
Non-carbonate CaO	Mass
Non-carbonate MgO	Mass
Amount of discarded CKD not recycled to the kiln	Mass

Table 1: Activity data for clinker-based CO_2 estimation method

[13] Examples of non-carbonated sources of CaO and MgO include calcium silicates or fly ash.

[14] Companies should keep in mind that manufacturing different types of cement which incorporate varying levels of CaO/MgO in the clinker could impact the accuracy of the plant-specific emission factor, if the separate batches of cement have significantly dissimilar CaO/MgO content levels. For example, companies could separately group for each cement manufacturing plant the activity data of a batch of clinker containing 60% CaO and 5% MgO by mass from a batch of clinker that contains 70% CaO and 2% MgO by mass.

Emission Factors

Clinker emission factor. Companies should derive an emission factor to calculate CO_2 emissions from clinker based on the percent of CaO and MgO in the clinker and adjusted to account for non-carbonate CaO and MgO. It reflects the $CaCO_3$ and $MgCO_3$ contained in the raw materials and excludes non-carbonate CaO and MgO. The emission factor will take the form of mass CO_2/mass clinker. Use the following steps to derive an emission factor.

- Determine amount of clinker produced,
- Determine CaO and MgO content of clinker
- Subtract the non-carbonate sources CaO and MgO from the total amount of CaO and MgO
- Multiply the remaining quantity of CaO and MgO by their respective stoichiometric ratios.

The following example illustrates how to derive and apply a clinker emission factor to calculate CO_2 emissions through the clinker-based methodology.

Example 1: Calculate CO_2 emissions from producing clinker and derive a clinker CO_2 emissions factor.

According to cement company XY's activity data, it produces 10 metric tons of clinker with CaO and MgO comprising 60% and 5% by mass, respectively. The activity data also shows that it imports 75kg of CaO per ton clinker. Cement company XY produces the remaining CaO and MgO content of its clinker on-site through the calcination of $CaCO_3$ and $MgCO_3$.

To determine the CO_2 emissions, follow the three steps presented below. Steps 1 and 2 show how to calculate total emissions; step 3 derives a clinker CO_2 emission factor.

Step 1: Subtract the imported CaO from the total amount of CaO;

10 metric tons clinker (.6) – 0.075 = 5.925 metric tons CaO

Step 2: Multiply the quantity of CaO and MgO by their respective stoichiometric ratios.

The CO_2/CaO stoichiometric ratio $= \dfrac{\text{molecular weight of } CO_2 \text{ (44g)}}{\text{molecular weight of CaO (56g)}}$
$= 0.785$
5.925 metric tons CaO (0.785) = 4.651 metric tons CO_2

The CO_2/MgO stoichiometric ratio $= \dfrac{\text{molecular weight of } CO_2 \text{ (44g)}}{\text{molecular weight of MgO (40g)}}$
$= 1.1$
10 metric tons clinker (.05) = 0.5 metric tons MgO
0.5 metric tons MgO (1.1) = 0.55 metric tons CO_2

<u>Total clinker CO_2 emissions</u> = 4.651 + 0.55 = 5.201 metric tons CO_2

Step 3: Derive a clinker CO_2 emissions factor.

Clinker CO_2 emissions factor = 5.201 tCO_2/10 t clinker
= 0.5201 tCO_2/metric ton clinker
= 520.1 $kgCO_2$/metric ton clinker

If companies lack good data on the CaO/MgO content of the clinker, then the Registry recommends a default emission factor of 525 kg CO_2/metric ton of clinker produced.[15]

[15] *The Cement CO_2 Protocol: CO2 Accounting and Reporting Standard for the Cement Industry,* Version 2.0, June 2005, The Cement Sustainability Initiative, WBCSD.

Cement kiln dust emission factor. Companies should also derive an emission factor associated with the CKD. It is likely that the CKD will contain uncalcinated $CaCO_3$ and $MgCO_3$. Therefore, using the clinker emission factor would yield an overestimation of emissions associated with CKD. The CKD emission factor is derived using the clinker emission factor and the degree of CKD calcination. Like the clinker emission factor, the CKD emission factor is based on the mass of CKD. The following equation demonstrates how to calculate a CKD emission factor.[16]

$$EF_{CKD} = \frac{\dfrac{EF_{Cli}}{1 + EF_{Cli}} \times d}{1 - \dfrac{EF_{Cli}}{1 + EF_{Cli}} \times d}$$

Where:

EF_{CKD}	=	Emission factor of partially calcinated Cement Kiln Dust (mass CO_2/ mass CKD)
EF_{Cli}	=	Clinker Emission Factor
d	=	Degree of CKD calcination

Equation 2: Calculating the CKD emission factor

The calcination rate, "d", should be based on loss-on-ignition data from each plant; it reflects the amount of CO_2 associated with creating CKD and expressed as a fraction of the total carbonate CO_2 in the raw materials. Alternatively, the Registry suggests using a default value of 1, which is conservative.

If companies have inadequate data to calculate a plant-specific CKD emission factor the Registry recommends assuming that the CO_2 emissions from CKD equal 2% of clinker CO_2 emissions.

Cement Manufacturing Efficiency Metric

The Registry considers the normalization of GHG emissions associated with fuel use and clinker or cement production vital to understanding the emissions characteristics of a cement company and in comparing performance across companies. In addition to the value of taking an inventory of absolute, entity-wide emissions, efficiency metrics enable cement companies to show the context in which their emissions are generated.

[16] Source: *The Cement CO_2 Protocol: CO2 Accounting and Reporting Standard for the Cement Industry,* Version 2.0, June 2005, The Cement Sustainability Initiative, WBCSD

The Registry's efficiency metric is the same as the performance indicator from The Cement CO_2 Protocol from WBCSD, except that it adds indirect emissions to the numerator. It relates

- direct and indirect emissions from a cement company to
- all clinker produced by the company for cement making or direct clinker sale, plus gypsum, limestone, CKD and all clinker substitutes consumed for blending, plus all cement substitutes produced.[17]

Equation 3 illustrates the efficiency metric: CO_2 emissions per ton of cementitious product.

$$\text{CO}_2\text{ emissions per ton of cementious product} = \frac{\text{Direct + Indirect CO}_2\text{ emissions from cement manufacturing}}{\text{Own clinker consumed or added to stock} + \text{own clinker sold directly} + \text{qypsum, limestone, CKD \& clinker substitutes consumed for blending} + \text{cement substitutes}}$$

Equation 3: Definition of specific (= unit-based) CO_2 emission.

This metric is widely used for monitoring emissions performance and calculating national cement industry benchmarks. It accounts for using clinker and cement substitutes as a CO_2 emission reduction strategy and intergrinding mineral components with clinker to make blended cements (i.e. clinker substitution) or as a binder (i.e. cement substitution).

The numerator covers direct and indirect emissions from

- mobile combustion sources
- stationary combustion sources
- process emissions (i.e., the calcination of raw material to produce clinker) and
- fugitive sources
- purchased and consumed electricity/steam/heat

The denominator does not necessarily equal total cement sales. It excludes:

- Bought clinker, used for cement production;
- Granulated slag which is sold to and ground by another company;
- Cement volumes which are traded without any processing.

[17] Like The Cement CO_2 Protocol from WBCSD, the Registry recommends that reporters include CKD that ultimately becomes incorporated in a cementitious product in the denominator of Equation 3. In contrast, landfilled dust should be excluded from the denominator. Additionally, we also use the term "cementitious products" or "binders" in the denominator, as it is a sum of clinker and mineral components; the denominator also excludes clinker bought from third parties for the production of cement, since this clinker is already included in the inventory of the third party.

Information on Other Emission Sources

As mentioned above, the Registry requires that reporters take a complete, entity-wide inventory of their GHG emissions. The following sections provide information for cement companies on determining emission from organic carbon in raw materials, mobile and stationary combustion, fugitive sources, and purchased electricity.

Organic Carbon in Raw Materials

A small amount of organic carbon is often entrained within the raw materials used for clinker production, which is converted to CO_2 during pyroprocessing. The Cement CO_2 Protocol from WBCSD indicates that the CO_2 emissions associated with the total organic carbon (TOC) content of raw materials is about 1% of the CO_2 emissions from clinker production and kiln fuel combustion (~10 kg CO_2/t clinker).[18]

Consistent with the Cement CO_2 Protocol from WBCSD, the Registry recommends calculating the CO_2 emissions from the TOC content of raw materials by applying an organic carbon factor to the amount of raw meal consumed then converting from carbon to CO_2.

CO_2 emissions from TOC in raw materials = $(TOC_{R.M.})$ (R.M.) (3.664)

Where:

$TOC_{R.M}$	=	Organic carbon content of raw material (%)
R.M.	=	The amount of raw material consumed (t/yr)
3.664	=	The CO_2 to C molar ratio

Equation 4: Calculating CO_2 emissions from TOC in raw materials

The Registry provides a default factor of 0.2% for the TOC of the raw materials. However, if companies believe they have significantly higher or lower carbon content then company specific data is appropriate; refer to the Cement CO_2 Protocol for specific guidance. The Registry suggests using plant-specific data to determine the amount of raw material consumed, which accounts for CKD not recycled to the kiln. Alternatively, companies can use a default raw meal to clinker ratio of 1.55.[19]

Direct Emissions from Mobile Combustion

Cement companies should refer to the GRP for guidance on calculating GHG emissions from mobile sources, including off-road quarry vehicles, and mobile quarry equipment, trucks, and company cars. Equipment that burns fossil fuel and is transported from one location to another (i.e., diesel generators) are not considered mobile combustion sources. Companies should refer to the section in the GRP on Direct

[18] This emission source will likely be classified as *deminimis* in a cement company's GHG inventory.

[19] *The Cement CO_2 Protocol: CO2 Accounting and Reporting Standard for the Cement Industry,* Version 2.0, June 2005, The Cement Sustainability Initiative, WBCSD

Emissions from Stationary Combustion for instructions on calculating emissions from these devices.

Mobile sources produce methane (CH_4) and nitrous oxide (N_2O) emissions, as well as CO_2. CO_2 emissions, the primary GHG emissions from mobile sources, are directly related to the quantity of fuel consumed. Thus emission factors are expressed in fuel quantity. On the other hand, combustion emissions of CH_4 and N_2O, while also related to fuel consumption, depend more on the emission control technologies employed in the vehicle. For this reason, their emission factors are typically expressed in terms of mass of compound emitted per distance traveled (gram/mile), and the preferred method of calculating these emissions is based on mileage.

The Registry's GRP provides emission factors for mobile combustion fuels and examples demonstrating the procedure for calculating emissions from mobile sources.

Direct Emissions from Stationary Combustion

The Registry's GRP serves as the primary resource for determining emissions from stationary combustion devices. Cement companies should calculate GHG emissions from cement kiln and non-kiln units based on fuel use and plant-specific fuel characteristics or by using default emission factors.[20]

In addition to burning conventional fossil fuels, such as coal, fuel oil, and natural gas, cement companies regularly combust waste-derived alternative fuels. These materials would, in most cases, be either landfilled or incinerated if not for their use by cement companies. The Registry classifies alternative waste fuels as either (1) alternative fossil fuels or (2) biomass fuels. GHG Emissions from alternative fossil fuels are not considered climate-neutral; thus they are included in a cement company's direct stationary combustion emissions inventory. In contrast, biomass fuels are considered carbon-neutral because their emissions are offset by the relatively quick uptake of CO_2 to re-grow biomass. Therefore, companies do not include emissions from biomass combustion in the direct stationary combustion emissions inventory. However, they must identify and report biomass CO_2 emissions as "biogenic emissions," in a category separate from fossil fuel emissions. Note that CH_4 and N_2O emissions from the combustion of biomass are not considered biogenic and should be calculated and reported as part of your direct emissions inventory

If companies have plant-specific kiln and non-kiln fuel emission factors, then this data should be used. The stationary combustion section in the GRP provides default emission factors for traditional fossil fuels; the following list consists of default emission factors for alternative fuels.

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[20] Cement companies that use continuous emissions monitoring systems (CEMS) for large stationary emissions sources are free to report that data to the Registry. Refer to the Registry's GRP and Power/Utility Protocol for guidance on CEMS. However, companies must be able to accurately allocate emissions to the appropriate emissions source if the CEMS device is reading emissions from multiple sources.

Alternative fuels	kg CO_2/GJ
Waste oil	80
Tires	85
Plastics	75
Solvents	75
Impregnated saw dust	75
Other fossil based wastes	80
Agricultural, organic, diaper waste, charcoal	110

Source: WBCSD/WRI, The Cement CO_2 Protocol

Direct Emissions from Fugitive Sources

Leaks in refrigerant systems are the most likely source of fugitive GHG emission for cement companies. Reporters should consult the Registry's GRP for guidance on calculating emissions from fugitive sources.

Indirect Emissions

Indirect emissions occur because of your organization's actions, but are produced by sources owned or controlled by another entity.[21] The Registry's GRP provides guidance on accounting for and reporting indirect emissions from purchased and consumed electricity, heat, and/or steam. In addition to reporting direct emissions from manufacturing cement and combusting fossil fuels, cement companies are required to report all significant indirect emissions.

Optional Reporting

In addition to reporting required emissions data, cement companies may also want to provide information about their other environmental efforts and activities as well as other indirect sources of emissions. This information might include

- upstream or downstream emissions from raw material purchases, such indirect CO_2 emissions from clinker purchases,
- emissions from carbon in waste water,
- product transport, or
- employee travel.

Optional emissions reports are not certified.

[21] World Resources Institute/World Business Council on Sustainable Development, *The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard* (2004).

Certification

The Registry's Cement Certification Protocol (CCP) is an appendix to its General Certification Protocol (GCP). The CCP complements the GCP by describing the core certification activities in the context of a cement company. Certification of a cement company's greenhouse gas (GHG) emissions report submitted to the Registry must be conducted in accordance with both the GCP and the CCP. The intended audience of the CCP is approved cement sector certifiers. However, cement companies may also find it useful to review this document to develop a better understanding of the certification activities associated with cement sector reporting to the Registry.

Certifiers of cement companies must read and be familiar with the following Registry reporting tools:

- General Reporting Protocol,
- General Certification Protocol,
- Cement Reporting Protocol,
- Cement Certification Protocol, and
- Climate Action Registry Reporting Online Tool (CARROT).

For more information on certifying a cement company's GHG emissions submitted to the Registry see the GCP and the CCP.

References

Calculating CO_2 Process Emissions from Cement Production, October 2001, ICF.

The Cement CO_2 Protocol: CO2 Accounting and Reporting Standard for the Cement Industry, Version 2.0, June 2005, The Cement Sustainability Initiative, WBCSD

Direct Emissions from the Cement Sector (Draft for Comment through August 2003), Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance

The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard (2004), WRI/WBCSD

Appendix A

The Cement-Based Methodology

The cement-based approach provides guidance on accounting for changes in emissions associated with altering the cement manufacturing process. This methodology incorporates the clinker-based approach, to the extent that the process-related emissions associated with producing clinker are accounted for here. Process-related CO_2 emissions from cement production are calculated by determining

- the amount of cement manufactured,
- the amount of clinker in the cement, adjusted for imported clinker,
- the amount of raw materials to produce the clinker, less non-carbonate sources CaO/MgO, and
- the amount of $CaCO_3$ and $MgCO_3$ in the raw material converted to $CaCO_3$ equivalent.

The following equation shows the general approach for calculating emissions according to the cement-based methodology.

$$CO_2 \text{ emissions} = (\text{Cem})\ (\text{Cli/Cem})\ (\text{RM/Cli})\ (CaCO_3\text{eq/RM})\ (CO_2\text{m.w.}/CaCO_3\text{m.w.})$$

Where:

Cem	=	Quantity of Cement Produced
Cli	=	Quantity of Clinker in Cement, adjusted for imports
RM	=	Quantity of Raw Materials to Produce Clinker
$CaCO_3$eq	=	Quantity of $CaCO_3$ equivalent
CO_2m.w.	=	Molecular weight of CO_2
$CaCO_3$m.w.	=	Molecular weight of $CaCO_3$

Equation 1: Calculating CO_2 emissions according to the cement-based methodology

Activity data on the quantity of raw materials, clinker, and cement produced should be collected on a plant-specific basis. Guidance on converting $MgCO_3$ to $CaCO_3$ equivalent is provided below. Emission factors associated with the cement-based methodology correspond to the clinker/cement ratio, the raw material/clinker ratio, and the $CaCO_3$eq/raw material ratio. For companies that have difficultly distinguishing between cement types and ambiguous data on raw materials and the clinker content of the cement the Registry provides default emission factors. The following sections provide information on collecting activity data and determining emission factors.

Activity Data

To calculate CO_2 emissions through the cement-based methodology companies need data on the following items:

Activity Data for Cement-Based CO_2 Estimation Method	Units
Cement produced	Mass
Clinker produced	Mass
Clinker exported	Mass
Clinker imported	Mass
Raw Material	Mass
Amount of $CaCO_3$ consumed	Mass
Amount of $MgCO_3$ consumed	Mass
Amount of imported non-carbonated CaO	Mass
Amount of imported non-carbonated MgO	Mass

Table 1: Activity Data for cement-based CO_2 estimation method

Emission Factors

In order to estimate emissions according to the cement-based methodology companies need to calculate three emission factors.

1. The clinker/cement ratio,
2. The raw material/clinker ratio, and
3. The $CaCO_3$eq/raw material ratio.

Clinker/cement emission factor. This ratio should capture differences in emissions associated with blended cements using clinker substitutes. However, if companies have unclear data on the clinker/cement ratio the Registry recommends using a default factor of 0.95 for Portland cements and 0.75 for blended cements.

Raw materials/clinker emission factor. This ratio represents the quantity of raw material used to produce an amount of clinker. The CKD formed during the production of clinker is accounted for in this factor. In lieu of plant-specific data the Registry recommends that for 1.54 metric tons of raw material consumed companies assume 1 metric ton of clinker is produced.

$CaCO_3$ eq/raw material emission factor. This ratio does incorporate the amount of $MgCO_3$ in the raw mix. However, this factor should not include any imported CaO or MgO. The following equation shows how to convert $MgCO_3$ into $CaCO_3$ equivalent.

$$CaCO_3eq = (MgCO_3)\ (CaCO_3m.w./MgCO_3m.w.)$$

Where:

$CaCO_3eq$	=	Calcium Carbonate equivalent
$MgCO_3$	=	Quantity of $MgCO_3$ in raw material
$CaCO_3m.w.$	=	Molecular weight of $CaCO_3$ (100g)
$MgCO_3m.w.$	=	Molecular weight of $MgCO_3$ (84g)

Equation 2: Calculating CO_2 emissions according to the clinker-based methodology

Similarly, companies can arrive at an equivalent amount of $CaCO_3$ by multiplying the amount of $MgCO_3$ in the raw mix by 1.19. The default factor in this case is 78%, which indicates that the $CaCO_3eq$ in the raw mix equals 78% by mass.

Importantly, the cement-based methodology assumes that the raw mix to produce clinker and CKD is completely calcinated. To account for uncalcinated materials in the CKD, companies should adjust the clinker/cement ratio or the $CaCO_3$/raw material ratio.